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PRECIPITATION THROUGHFALL AND STEMFLOW INVESTIGATIONS AT PLASTIC AND HARP LAKE WATERSHEDS IN THE MUSKOKA-HALIBURTON AREA OF ONTARIO, 1982 TO 1986

DATA REPORT

JANUARY 1994

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PRECIPITATION THROUGHFALL AND STEMFLOW INVESTIGATIONS AT PLASTIC AND HARP LAKE WATERSHEDS IN THE MUSKOKA-HALIBURTON AREA OF ONTARIO, 1982 TO 1986

DATA REPORT

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EXECUTIVE SUMMARY

Between 1982 and 1986, the Biogeochemical Studies program of the Acidic Precipitation in Ontario Study included in-depth investigations of the interactions between incident precipitation and forest trees in two catchments in the Muskoka-Haliburton area of Ontario. These investigations were conducted under a contract with the Faculty of Forestry, University of Toronto.

The catchments had contrasting cover characteristics, and were under hydrologic and chemical budget monitoring by other studies. Incident precipitation, throughfall and stemflow were measured and sampled by distributing collectors within the basins using stratified and fixed plot sampling strategies. Concentrations of the major ions in the samples were determined.

The forest cover characteristics of distinct stands on the two basins are described in terms of species composition, basal area, stem frequency and areal extent.

The hydrologic and chemical data were scrutinized and edited to ensure that all possible observations were accounted for, conformed to chemical laws and intuitive principles, and agreed with concomitant observations. This report describes these validation and editorial procedures.

The appendices to this report include data tables, in microcomputer file format, containing hydrologic and chemical characteristics of incident precipitation, throughfall and stemflow collected during the course of this study.

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1 INTRODUCTION

In 1982, the Air Resources Branch of the Ministry of the Environment contracted with the Faculty of Forestry, University of Toronto to undertake investigations on two forested watersheds in the Muskoka-Haliburton area of Ontario. These investigations were conducted under the auspices of the Acidic Precipitation in Ontario Study (APIOS) and comprised part of the 'Biogeochemical Studies' program of APIOS.

A major component of these investigations was the monitoring of hydrological pathways and the flux of materials in and out of the watershed as well as between watershed compartments. Such monitoring included the collection and chemical characterization of precipitation water at three points along the path from the atmosphere to the forest floor. The first of these was unaltered incident precipitation. The second point was throughfall, defined as precipitation water that had been at least partially intercepted by the forest canopy before reaching the forest floor. The third was stemflow, consisting of water that had been intercepted by the canopy and had flowed down the tree bole.

This report describes the methodologies employed in monitoring incident precipitation, throughfall and stemflow and the rationale behind these methods. It describes the techniques used to validate data and generate data estimates in cases were the original data were rejected as invalid or were not collected. Appendices to this report consist of MS-DOS diskettes containing data tables.

2 STUDY SITES

2.1 SELECTION CRITERIA

The watershed basins selected for this study were located in the Muskoka-Haliburton area of south central Ontario and are designated as Plastic Lake No. 1 and Harp Lake No. 4. These basins met the selection criteria which were:

- The basins had defined catchment areas and were headwater basins receiving chemical inputs solely from atmospheric sources.
- The basins were in geographic proximity and subjected to similar and concurrent meteorologic activity and atmospheric loading of long-range transport air pollutants.
- The basins had contrasting characteristics of forest cover, soil type and depth and demonstrated differences in the water quality of streams draining the basins.

- The streams draining the basins were gauged and the water quality monitored.
- The basins had reliable all-season access and reasonable assurance of tenure.

2.2 PLASTIC LAKE NO. 1

Plastic Lake is located at latitude 45′ 11′ N and longitude 78′ 49′ W in Sherborne Township, Haliburton County. The lake surface is at an elevation of 378 metres a.s.l. It is a small Precambrian Shield headwater lake, 32.14 hectares in size and receives drainage from a 92.50 hectare catchment. The Plastic Lake No. 1 basin occupies a westerly sector of the lake catchment and is 23.34 hectares in size. This basin is drained by a perennial stream which is gauged by a V-notch weir at 381 metres. The maximum elevation in the basin is 420 metres, generating a relief of 39 metres.

The basin is defined primarily by natural topography. The exception is an easterly section of boundary which follows a gravel road bed. This road provides vehicle access to the basin during the summer and fall seasons. Winter access is by snowmobile and spring access is by all terrain cycle. All land comprising the basin is managed by the Leslie M. Frost Natural Resources Centre of the Ontario Ministry of Natural Resources. There is no development on any part of the lake catchment.

The bedrock of the basin is dominated by gneiss of igneous origin with outcrops of metasedimentary features. Rock outcrops are frequent, otherwise the surficial geology consists of thin basal tills on the uplands and organic deposits in the lowlands. The majority of the soils belong to the podzolic order and vary from zero to approximately two meters in depth.

2.3 HARP LAKE NO. 4

Harp Lake is located at latitude 45′ 23′ N and longitude 79′ 8′ W in Chaffey Township, Muskoka District Municipality. The lake surface is at an elevation of 327 metres a.s.l. It is also a headwater lake, but is substantially larger at 71.38 hectares and drains a 470.66 hectare catchment. The Harp Lake No. 4 basin is 119.09 hectares in size and occupies a westerly sector of the lake catchment. The basin is drained by a perennial stream originating in a pond but receiving input from tributaries along its course to the lake. The stream is gauged by a rectangular weir at an elevation of 329 metres. The maximum elevation on the basin is 420 metres, generating a relief of 91 metres.

This basin is also primarily defined by natural topography except for a relatively short section of gravel road bed on the easterly extreme of the basin. This road can be used by conventional motor vehicles year round. All land comprising the basin is privately owned. Harp Lake is developed with cottages and year-round homes. Some sections of the Harp 4 basin have been logged and are un-forested.

The bedrock of this basin is primarily amphibolite and schist. The surficial geology consists of basal tills on the uplands and sand deposits, frequently covered by peat, in the lowlands. Bedrock is only exposed at bedrock ridges. Podzolic soils dominate the uplands, with organic soils occurring in the lowland peat areas. Till depth is highly variable and can exceed 50 metres in valley bottoms.

3 FOREST COVER

3.1 SURVEY TECHNIQUES

Details on the techniques used to survey the standing crop characteristics of the Plastic Lake No. 1 and Harp Lake No. 4 basins are given in a report by Lozano and Parton (1987)[1]. All forest cover data presented in this section are taken or adapted from this report.

Briefly, the survey consisted of delineating a fixed grid system on the watershed and using a wedge prism with a basal area factor of 2.0 m^2/ha to determine the basal area and stem density of different species at each grid intersection. This was followed by caliper measurements of each stem within the prism plot for stems greater than 10 cm Diameter at Breast Height (DBH) at Plastic 1 and greater than 12 cm DBH at Harp 4 to provide a diameter class distribution for each species.

The basins were also divided into forest cover stands based on distinguishable differences in species composition as determined by air photo interpretation and ground observations. The Plastic 1 basin was divided into five forest cover types plus rock outcrop and alder swamp areas. The Harp 4 basin was divided into 13 forest cover types plus un-forested, open water and road areas.

---

[1] Unpublished Report: Forest Cover Characteristics of the Harp #4 and Plastic #1 Subcatchments of the Southern Ontario Biogeochemical Study, Faculty of Forestry, University of Toronto

The locations of each of the stand types and other geographic features comprising Plastic Lake No. 1 and Harp Lake No. 4 basins are given in Figures 1 and 2 respectively. Also represented in these figures are the locations on the basins of the incident precipitation, throughfall and stemflow sampling stations to be discussed later.

3.2 CHARACTERISTICS

The characteristics of each forest stand type are summarized in Tables 1 through 4. Two approaches are used in these summaries. In Tables 1 and 2 the basal areas occupied by the various species are expressed as percentages of the total basal area of the standing crop. In Tables 3 and 4 the frequencies of occurrence of individual stems of each species are summarized. In both approaches, the summaries are limited by exclusion of individual trees smaller than the minimum DBHs discussed above.

Tables 1 through 4 also contain summaries of the characteristics of the total forested area of each basin. These were derived by weighting the individual stand characteristics by the areas occupied by those stands. Un-forested land, open water, swamps, bedrock outcrops and roads were not included in the weighting. Areas occupied by these features are reported separately.

The order of dominance of the species differs depending on whether basal area percentage or stem frequency is used for ranking. This reflects the stem diameter distribution for the different species. Small stem diameter species, or a predominance of younger trees will contribute to higher frequency values, while predominance of larger species or older trees will contribute to higher percent basal area values.

Basal area can be considered a better indicator of the dominance by a given species since it considers both the number and size of the trees and intuitively the dominance of the canopy.

The dominant species at Plastic 1 are White Pine and Eastern Hemlock, both conifers. Soft Maple, Red Oak and White Birch are the major deciduous species present. White Cedar is also a major component of the basin but it is restricted to a wet, swampy, inaccessible topographic depression and to the gullies leading to this swamp area.

One single stand type constitutes 54.5 % of the total basin area. Stand A is dominated by the two major conifer species with only Soft Maple and Red Oak as significant contributors to the stand. White Pine and Eastern Hemlock are also major contributors to the remaining forested stands with the exception of the cedar swamp designated as Stand C.

Harp 4 has been divided into 13 forest stand types. The size of this basin, about five times the area of Plastic 1, is the major reason for this apparent finer stratification. Most of the stand types, specifically the larger ones, are dominated by deciduous species. Hard Maple and Soft Maple constitute 51.3 % of the basin basal area. Largetooth Aspen, American Beech and Yellow Birch are also significant components. Eastern Hemlock is the major component of Stand H in the southwestern part of the basin.

The differences between the two basins can be summarized as follows. Plastic Lake No. 1 is a small catchment basin characterized by very thin podzolic soils and dominated by White Pine and Eastern Hemlock, both conifer species. Secondary species are various hardwoods. Harp Lake No. 4 is a much larger basin with deeper podzolic soil and mixed hardwoods, which are dominated by Hard Maple and Soft Maple. Other deciduous species contribute most of the balance of the standing crop. The only conifer of significance is Eastern Hemlock, but it is confined to a unique forest stand.

TABLE 1: Plastic Lake No. 1 Forest Cover - Basal Area

Stand	Cover Characteristics*	Area (ha)	% of Total
A	Pw_{47} He_{19} Or_{9} Ms_{9} Bw_{5} O_{10}	12.72	54.50
B	Ms_{28} Pw_{21} Ce_{12} Bw_{11} Or_{9} He_{9} O_{10}	3.32	14.22
C	Ce_{71} Sb_{13} Sw_{6} O_{10}	2.18	9.34
D	Pw_{32} Ms_{23} Or_{18} Bw_{11} O_{16}	1.90	8.14
E	He_{35} Or_{14} Pw_{14} Bw_{14} Ms_{11} Po_{8} O_{3}	1.80	7.71
F	Exposed Bedrock	0.85	3.64
G	Alder Swamp	0.57	2.44
	Watershed Basin Totals	23.34	100.00
PL 1**	Pw_{37} He_{17} Ms_{13} Or_{10} Ce_{7} Bw_{7} O_{9}	21.92	93.92

* Subscript number following the species code represents the percentage of the basal area of the stand or forested portion of watershed contributed to by that species. 'Other' species include those contributing less than five percent of the basal area.

** Forested stand area weighted average cover characteristics.

Species Codes					
Bw	White Birch	Or	Red Oak	Sb	Black Spruce
Ce	White Cedar	Po	Poplar	Sw	White Spruce
He	Hemlock	Pw	White Pine	O	Other Species
Ms	Soft Maple				

TABLE 2: Harp Lake No. 4 Forest Cover - Basal Area

Stand	Cover Characteristics*	Area (ha)	% of Total
A	Mh_{32} Ms_{18} Be_{14} He_{13} O_{22}	21.78	18.29
B	Mh_{48} Po_{9} Ms_{8} Bwd_{8} By_{7} Fb_{5} O_{15}	15.82	13.28
C	Mh_{34} Ms_{16} Po_{14} Bw_{10} Be_{8} O_{19}	14.33	12.03
D	Mh_{39} By_{21} Ms_{11} Po_{6} Bw_{5} O_{18}	11.40	9.57
E	Mh_{37} Ms_{22} Pw_{9} Po_{7} Chb_{5} Be_{5} O_{15}	9.31	7.82
F	Mh_{41} Ms_{18} By_{10} Po_{10} Be_{6} O_{16}	7.81	6.56
G	Non-Forested	6.79	5.70
H	He_{26} Ms_{13} Sb_{13} Fb_{11} Bwd_{10} Ce_{10} O_{17}	6.63	5.57
I	Mh_{50} Ms_{17} By_{9} Po_{7} O_{18}	5.14	4.32
J	Mh_{82} Be_{5} O_{13}	4.55	3.82
K	Ms_{32} Mh_{29} Be_{11} Chb_{6} By_{5} O_{16}	3.47	2.91
L	Mh_{53} Bwd_{11} By_{11} Aw_{6} O_{18}	2.87	2.41
M	Fb_{23} Ce_{20} Sw_{14} Ab_{10} By_{10} Bwd_{7} Bw_{5} O_{11}	2.77	2.33
N	Po_{44} Mh_{20} Be_{15} Ms_{11} O_{10}	1.38	1.16
O	Surface Water & Road	5.04	4.23
	Watershed Basin Totals	119.09	100.00
HL 4**	Mh_{37} Ms_{14} Po_{7} Be_{7} By_{7} He_{6} O_{23}	107.26	90.07

* Subscript number following the species code represents the percentage of the basal area of the stand or forested portion of watershed contributed to by that species. 'Other' species include those contributing less than five percent of the basal area.

** Forested stand area weighted average cover characteristics.

Species Codes

Ab	Black Ash	Ce	Cedar	Po	Poplar
Aw	White Ash	Chb	Black Cherry	Pw	White Pine
Be	Beech	Fb	Balsam Fir	Sb	Black Spruce
Bw	White Birch	He	Hemlock	Sw	White Spruce
Bwd	Basswood	Mh	Hard Maple	O	Other species
By	Yellow Birch	Ms	Soft Maple		

TABLE 3: Plastic Lake No. 1 Forest Cover - Stem Frequency

Stand	Cover Characteristics*	Area (ha)	% of Total
A	Pw_{29} He_{27} Ms_{17} Ce_{7} Or_{6} Bw_{5} O_{10}	12.72	54.50
B	Ms_{37} Ce_{19} Pw_{11} Bw_{10} He_{9} Fb_{6} O_{9}	3.32	14.22
C	Ce_{76} Sb_{12} Sw_{6} O_{6}	2.18	9.34
D	Ms_{40} Pw_{19} Bw_{10} Or_{8} He_{6} Iw_{6} O_{11}	1.90	8.14
E	He_{48} Ms_{15} Bw_{14} Or_{9} Pw_{8} O_{7}	1.80	7.71
F	Exposed Bedrock	0.85	3.64
G	Alder Swamp	0.57	2.44
	Watershed Basin Totals	23.34	100.00
PL 1**	He_{22} Pw_{21} Ms_{20} Ce_{14} Bw_{7} Or_{5} O_{11}	21.92	93.92

* Subscript number following the species code represents the stem frequency of that species in the stand or forested portion of the watershed. 'Other' species include those contributing less than five percent of the stem frequency.

** Forested stand area weighted average cover characteristics.

Species Codes					
Bw	White Birch	Or	Red Oak	Sb	Black Spruce
Ce	White Cedar	Po	Poplar	Sw	White Spruce
He	Hemlock	Pw	White Pine	O	Other Species
Ms	Soft Maple				

TABLE 4: Harp Lake No. 4 Forest Cover - Stem Frequency

Stand	Cover Characteristics*	Area (ha)	% of Total
A	Mh_{33} Ms_{22} Be_{11} He_{8} Bwd_{6} O_{21}	21.78	18.29
B	Mh_{52} Ms_{8} Po_{8} Fb_{6} Bwd_{6} By_{5} O_{15}	15.82	13.28
C	Mh_{35} Ms_{18} Bw_{10} Po_{9} Be_{8} Iw_{6} O_{14}	14.33	12.03
D	Mh_{43} By_{19} Ms_{9} Ab_{5} O_{24}	11.40	9.57
E	Mh_{35} Ms_{15} Pw_{12} Po_{11} Chb_{9} Bw_{6} O_{13}	9.31	7.82
F	Mh_{49} Ms_{14} By_{8} Be_{7} Po_{7} Ab_{6} O_{10}	7.81	6.56
G	Non-Forested	6.79	5.70
H	He_{22} Fb_{17} Bwd_{15} Ms_{14} Ce_{11} Sb_{9} O_{13}	6.63	5.57
I	Mh_{59} Ms_{13} By_{7} Po_{6} O_{15}	5.14	4.32
J	Mh_{81} Iw_{7} Be_{5} O_{7}	4.55	3.82
K	Mh_{37} Ms_{25} Be_{9} Chb_{9} By_{6} O_{15}	3.47	2.91
L	Mh_{53} Bwd_{11} By_{10} Aw_{8} O_{17}	2.87	2.41
M	Fb_{24} Ce_{25} Ab_{13} Sw_{11} Bwd_{8} By_{7} Bw_{6} O_{7}	2.77	2.33
N	Po_{30} Mh_{24} Be_{23} Ms_{16} O_{7}	1.38	1.16
O	Surface Water & Road	5.04	4.23
	Watershed Basin Totals	119.09	100.00
HL 4**	Mh_{38} Ms_{14} Be_{6} Po_{5} By_{5} O_{31}	107.26	90.07

* Subscript number following the species code represents the stem frequency of that species in the stand or forested portion of the watershed. 'Other' species include those contributing less than five percent of the stem frequency.

** Forested stand area weighted average cover characteristics.

Species Codes

Ab	Black Ash	Ce	Cedar	Po	Poplar
Aw	White Ash	Chb	Black Cherry	Pw	White Pine
Be	Beech	Fb	Balsam Fir	Sb	Black Spruce
Bw	White Birch	He	Hemlock	Sw	White Spruce
Bwd	Basswood	Mh	Hard Maple	O	Other species
By	Yellow Birch	Ms	Soft Maple		

FIGURE 1: Plastic Lake No. 1 Forest Stand and Collector Locations

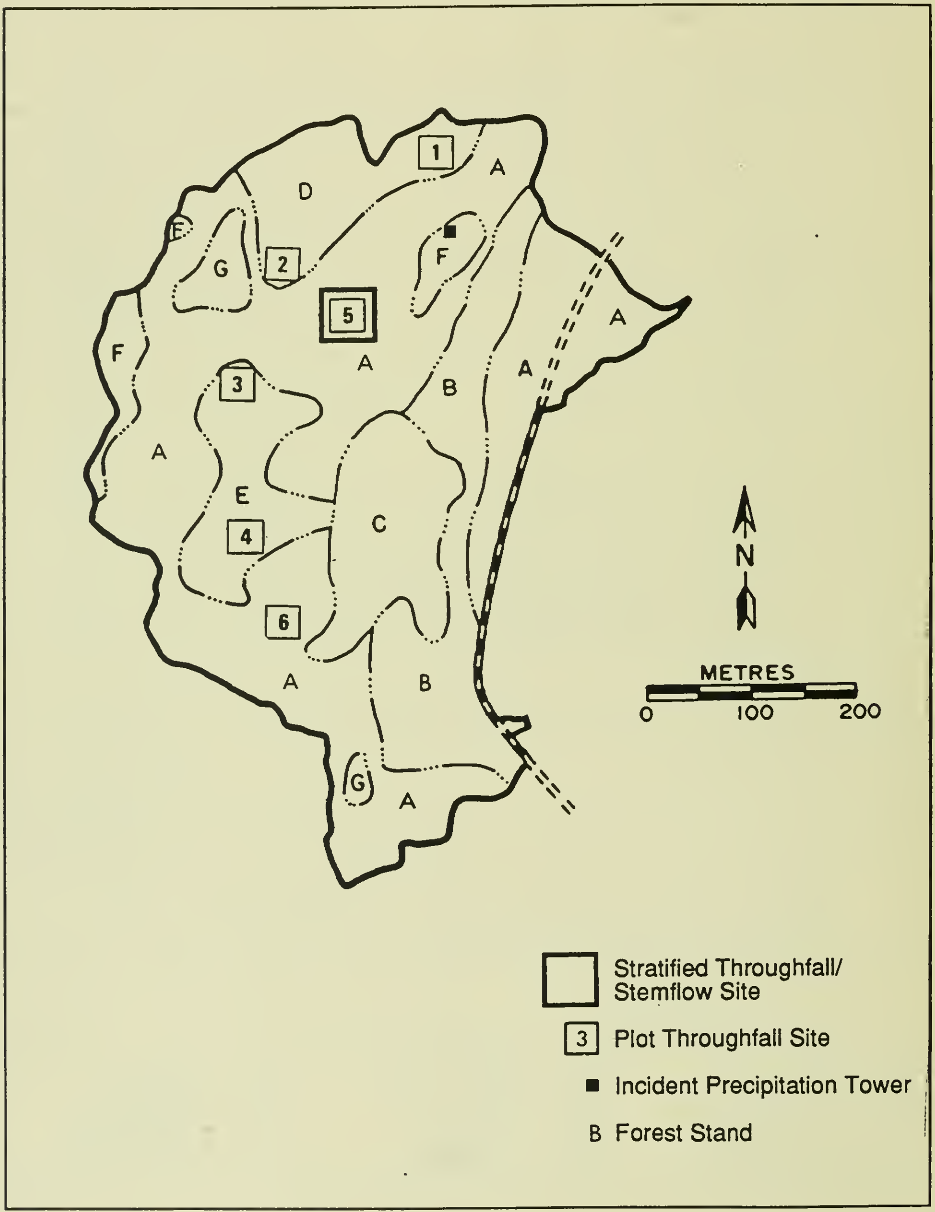
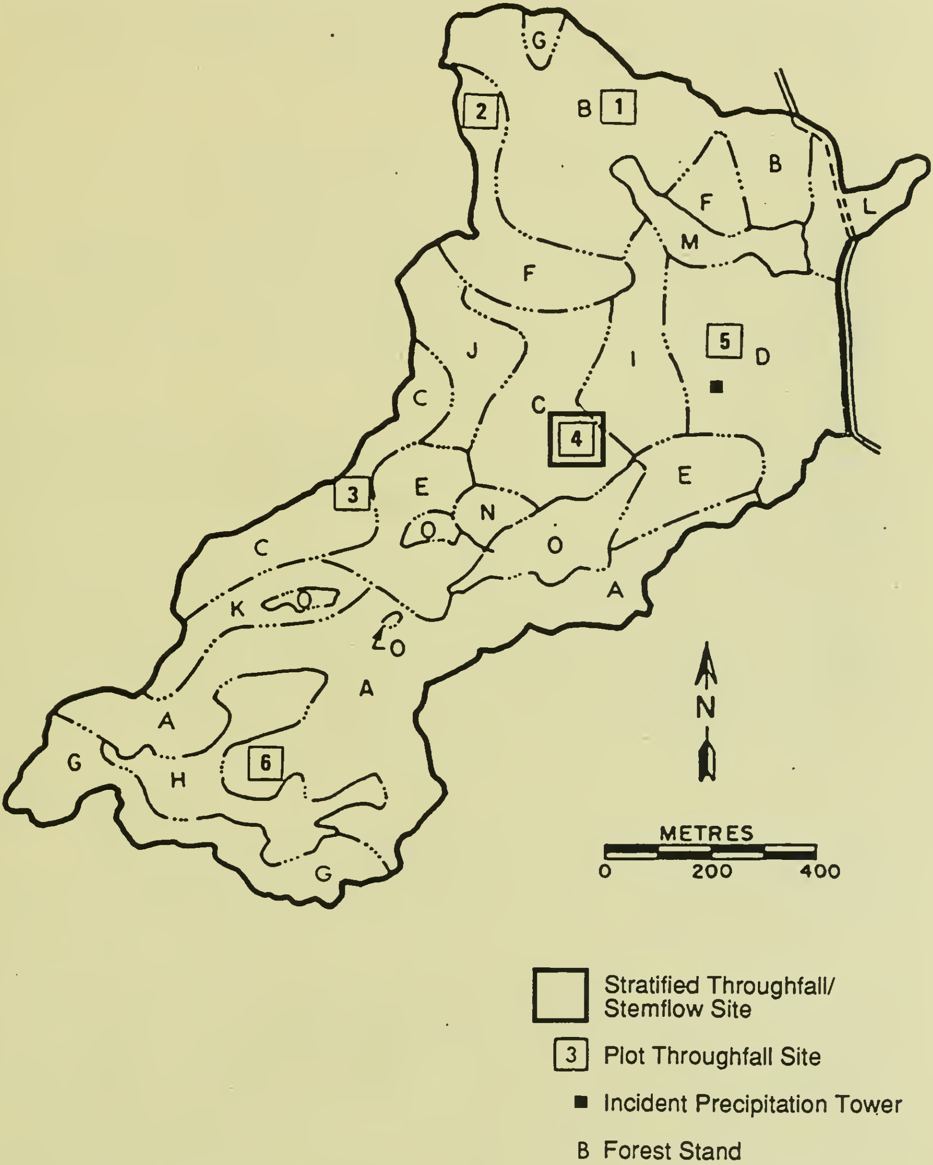


FIGURE 2: Harp Lake No. 4 Forest Stand and Collector Locations



4 COLLECTOR DESIGN AND SAMPLING STRATEGIES

4.1 INCIDENT PRECIPITATION

Incident precipitation was collected by two types of collectors, depending on whether the anticipated precipitation was rain or snow. Both were open continuously and are considered 'bulk' collectors.

The rain collector consisted of a polyethylene funnel, 28.8 cm in diameter finished to knife edge and with a catch area of 650 cm^2. The funnel stem opening was covered with a 100 micron nylon mesh. The stem was inserted into a hole in the lid of a five litre polyethylene cylinder and sealed with laboratory film. The inside of the cylinder was lined with a bag consisting of a polyethylene interior, laminated to a nylon exterior to improve puncture resistance. Two identical collectors were used in the collection of incident rain.

The snow collector consisted of a 80 litre, polyethylene refuse container lined with a larger polyethylene/nylon bag. A polyethylene ring was sized to fit the inside perimeter of the top of the container. This ring kept the bag in place and provided a catch area of 1600 cm^2.

Incident precipitation was collected above the canopy by erecting a tower of construction scaffolding and placing the collectors on the top platform. At Plastic 1, the tower was located at a bedrock outcrop, while at Harp 4 the tower was located on a small hilltop. The collectors were at an elevation of 15 meters above the ground. Figures 1 and 2 indicate the locations of these towers in the respective basins.

Construction of the towers permitted the placement of incident collectors in proximity to the respective throughfall collectors without relying on or creating a clear area. The contamination of incident precipitation samples by wind blown tree litter (leaves, seeds, pollen) was also reduced.

In addition to the two incident rain funnels, a standard rain gauge and a battery-operated, tipping rain gauge were also installed on the towers. The standard gauge would be used to resolve any funnel collected depth inconsistencies, while the tipping bucket would provide a continuous record of rain activity; start and end times, intensity, duration. During the snow season, incident precipitation was collected by a single 80 litre snow collector. The gauges were not appropriate for winter use.

At the Plastic 1 bedrock outcrop, a standard rain gauge or one of the snow collectors was also installed at ground level near the tower. The surrounding forest provided a much-needed wind screen, especially for the snow collector. The precipitation depths measured by this collector would eventually displace the measurements recorded by the snow collector on the tower. The latter, it was determined, underestimated the amount of incident snow.

A similar bedrock outcrop or other type of forest clearing was not available at the Harp 4 basin.

Throughout the rain seasons, incident precipitation was sampled by 'event'. An event was defined as a period of precipitation activity isolated by 24 hours of dry weather. During the snow season, collections were made weekly, given that there was an accumulation of precipitation during the preceding week and there was no precipitation occurring on the scheduled collection day. Otherwise the collection was made the following week or when activity ceased.

The collection consisted of removing and sealing the liner bags. On-site weighing of the sample was performed with a spring scale to provide a more reliable volume estimate in case of sample loss during transport. New bags were installed and either the funnel or snow collector ring replaced. At 10 to 14 day intervals, lab-washed rain funnels were installed during the collection visits to prevent the accumulation of organic materials, tars and resins, from the trees on the funnel surfaces. Washing was performed with laboratory detergent followed by several rinses with deionized water.

4.2 THROUGHFALL

The throughfall collectors were identical to the incident precipitation collectors in design. Also, sample collection, collector maintenance and volume recording procedures were identical and were performed concurrently with those for the incident precipitation.

During the course of this study, two distinct throughfall sample collector placement strategies were employed. The first strategy involved positioning the collectors beneath 'target' canopies that represented the range of species and diameter classes in the basin. This stratified approach had two phases, an intense phase and a reduced phase where the number of throughfall collection locations was lower. The second strategy utilized a fixed plot in the different, major stand types. In addition, within the reduced stratified sampling period, sampling beneath replicated target canopies was employed.

The aim of each strategy was to characterize the role of the whole of the forested area of each basin in altering both the quantity and quality of precipitation reaching the forest floor. The exception to this objective occurred with the exclusion of the cedar swamp area, Stand H, at Plastic 1. This stand was too inaccessible for routine monitoring.

The first stage in designing the stratified approach consisted of determining the number of throughfall collector locations which could be attended to with finite logistic resources. Twenty five stations at each basin were the maximum which could be established. The second phase was to determine the canopy types which could be addressed with these collectors. At the Plastic 1 basin, the four dominant species were selected as target canopy types. At Harp 4, the five most dominant species were selected. Dominance was defined as higher basal area for reasons discussed above. These four and five species collectively comprised 77 and 72 percent of the basal area of the forest trees in the Plastic 1 and Harp 4 basins respectively. Finally the collector locations were stratified in proportions that represented the relative dominance of each of the selected species on the watershed and encompassed the range of stem diameters exhibited by that species.

Two or three (for larger trees) of the funnel-type rain collectors were positioned within the drip line of each target canopy. The volume of each individual collector was determined, however the samples would be bulked prior to chemical analysis. A single snow throughfall collector was similarly positioned. The position of each independent collector was marked so that it could be returned to the same position at the beginning of the given season if required.

Tables 5 and 6 detail the distribution of throughfall collectors during the different phases of the stratified strategy. The alphabetic codes refers to the target species and the sequential numbers identifying each station within the species group. Within each group, the numbers represent increasingly larger diameters. Stations identified with the characters 'b' and 'c' represent the replicates of certain target canopies which were established to measure the degree of variability in throughfall depth and chemical composition that may occur under target canopies of like species and similar stem diameter and crown shape and size.

This sampling strategy should not be construed as attempting to isolate the role of a given tree species. The influence of the overstory at locations targeting smaller diameter trees or the influence of the understory near the larger trees was present and no attempt was made to reduce it. The strategy attempted to ensure that collectors were placed in a variety of micro-cover types. This would permit a simple extrapolation of the observations made at the selected locations to the whole basin, with the exception of certain stands previously discussed.

The stratified sampling was suspended and replaced by a fixed plot strategy in April, 1985. Six plot locations were established in each basin. At Plastic 1, two plots were established in each of stands A, D and E. At Harp 4, one plot was established in each of stands A, B, D and F. Two plots were established in stand C. Figures 1 and 2 show the locations of these plots in the respective basins.

The Plastic 1 stands selected to contain the plots, collectively resembled the overall cover characteristics of the basin. On an areal basis, stands A, D and E accounted for 70 % of the basin and 75 % of the forested area. The two stands excluded from this coverage, while representing the second and third largest stands, were unique and presented logistic problems. Both of these stands occupied low lying areas, the gully and the adjacent slopes, and the cedar swamp.

The Harp 4 stands A, B, C, D and F likewise represented the overall cover of the basin and included the largest stands. These stands represented 60 % of the basin area and 66 % of the forested area. Stand E was excluded for access reasons. Stand C received two plots because it in itself best represented the basin forest cover. Harp 4 also contained a number of minor yet distinct stands which could not be addressed with finite resources. Most of these were hardwood dominated as were the primary stands. Their distiction lay in the relative dominance of different species. The exceptions were two stands, H and M, with conifer dominance.

The location of each plot within a stand was selected to represent a 'typical' cover condition in that stand with respect to species composition, tree size and stocking density. The plots were 15 x 15 meters and were staked at 3-meter intervals. Five rain or three snow collectors were randomly re-distributed among the stake points during each clean rain funnel exchange or during each snow period collection. The volume of each individual collector was determined, however the samples were bulked prior to any chemical analysis.

Tables 5 and 6 contain dates with which the first and last collection in each strategy or phase was identified. A Reference Number identifies each collection over the term of the study. This designation will be discussed later. Finally, these tables report the number of collections made, the number of throughfall stations active and the total number of samples collected.

4.3 STEMFLOW

The design of the stemflow collector consisted of a length of laboratory tubing, brand name 'Tygon Formulation 2506', of 1" O.D. and 3/4" I.D. This tubing was split longitudinally, wrapped in a downward spiral around the tree bole, fastened with stainless steel staples and sealed to the bark with acrylic caulking. On species with rough bark, the bark was shaved to improve the seal while taking care not to damage the cambium layer. The lower, unsplit end of the tubing was inserted into a hole in the lid of a plastic refuse container which was lined with a disposable polyethylene refuse bag. The capacity of the container was 125 litres.

The collection of samples involved weighing the liner bag with a spring scale, or if the sample was too large, using a calibrated plastic rod to measure the volume of the sample. The sample was stirred to ensure complete mixing and an aliquot was taken into a 475 mL polystyrene jar. Excess sample was poured onto the ground at the base of the respective bole.

The strategies for sampling of stemflow paralleled those of throughfall. There was, however was no sampling of stemflow during the fixed plot throughfall sampling period. Stemflow collectors were used on the bole of each of stratified period target canopies, including the replicated canopies, at the same time and for the same duration.

To reduce the logistic demands on the field and laboratory staff, a restriction on the definition of a stemflow sample was placed. It was assumed that a sample existed if more than one litre was collected. The rational behind this restriction was that the bole beneath the collar would have absorbed some of the stemflow water if it had not been intercepted. All stemflow volumes were reduced by this amount to maintain consistency. This restriction was admittedly arbitrary, but in light of the large volumes of such samples, it was unlikely to present a noticeable bias to the data. It did, however, ensure that each stemflow sample would be of sufficient size for complete chemical analysis.

5 SAMPLE PROCESSING AND CHEMICAL ANALYSIS

Upon collection and weighing, all samples were transported to the field laboratory at the Dorset Research Center and processed for chemical analysis.

The weight of the contents of each bag was determined on an electronic pan balance to improve accuracy of this measure prior to bulking. In cases of large quantities of sample, exceeding the capacity of the lab balance, the weight determined in the field was used. Aliquots of incident rain and throughfall were transferred to disposable 475 mL polystyrene jars.

These jars, along with those containing the stemflow were delivered to the analytical laboratory at the research center where the pH and Gran acidity were determined. These measurements were made within the same day to within five days of sample collection in the field depending on logistic constraints. The remaining sample was shipped to the Laboratory Services Branch (LSB) laboratory in Toronto for determination of major ions.

Details pertaining to the analytical methods can be found in various analytical methodology documents developed by LSB. In brief, pH was determined with a pH meter and combination glass-calomel electrode and Gran acidity by titration with a base to a fixed end-point. The anions sulphate, nitrate and chloride were determined by ion chromatography, while the base cations calcium, magnesium, potassium and sodium were determined by flame atomic absorbtion spectrophotometry. Ammonium ions were determined by a colourimetric technique. Phosphate ions were also determined but their concentrations were too frequently below detection limits to be useful.

TABLE 5: Sampling Periods and Strategies at Plastic Lake No. 1

SAMPLE DATE (first)	830105	840215	840418	840903	850419
SAMPLE DATE (last)	840208	840411	840830	850416	860415
REF. NO. (first)	36	104	112	146	187
REF. NO. (last)	103	111	144	185	255
Incident	-------	-------	-------	-------	-------
PW 1	-------				
PW 2	-------				
PW 3	-------	-------	-------	-------	
PW 3b			-------		
PW 3c			-------		
PW 4	-------				
PW 5	-------				
PW 6	-------				
PW 7	-------	-------	-------	-------	
PW 7b			-------		
PW 7c			-------		
PW 8	-------				
PW 9	-------				
PW 10	-------				
PW 11	-------	-------	-------	-------	
PW 11b			-------		
PW 11c			-------		
PW 12	-------				
HE 1	-------				
HE 2	-------				
HE 3	-------	-------	-------	-------	
HE 3b			-------		
HE 3c			-------		
HE 4	-------				
HE 5	-------				
HE 6	-------	-------	-------	-------	
HE 6b			-------		
HE 6c			-------		
MS 1	-------				
MS 2	-------	-------	-------	-------	
MS 2b			-------		
MS 3	-------				
MS 4	-------	-------	-------	-------	
MS 4b			-------		
OR 1	-------				
OR 2	-------	-------	-------	-------	
OR 3	-------				
Plot 1					------*
Plot 2					------*
Plot 3					------*
Plot 4					------*
Plot 5					------*
Plot 6					------*
Collections	64	8	28	35	61
Incident Samples	64	8	28	35	61
Throughfall Stations	25	8	20	8	6
Throughfall Samples	1600	64	560	280	366
Stemflow Stations	25	8	20	8	0
Stemflow Samples	556	31	246	124	0

------* = Stemflow not collected

TABLE 6: Sampling Periods and Strategies at Harp Lake No. 4

SAMPLE DATE (first)	830105	840215	840418	840831	850428
SAMPLE DATE (last)	840208	840411	840830	850423	860424
REF. NO. (first)	36	104	112	145	188
REF. NO. (last)	103	111	144	186	256
Incident	--------	--------	--------	--------	--------
MH 1	--------	--------	--------	--------	
MH 1b			--------		
MH 1c			--------		
MH 2	--------				
MH 3	--------				
MH 4	--------				
MH 5	--------	--------	--------	--------	
MH 5b			--------		
MH 5c			--------		
MH 6	--------				
MH 7	--------				
MH 8	--------				
MH 9	--------				
MH 10	--------				
MH 11	--------	--------	--------	--------	
MH 11b			--------		
MH 11c			--------		
MH 12	--------				
MH 13	-------*				
MS 1	--------				
MS 2	--------	--------	--------	--------	
MS 2b			--------		
MS 3	--------				
MS 4	--------	--------	--------	--------	
MS 4b			--------		
MS 5	--------				
MS 6	--------				
PO 1	--------	--------	--------	--------	
PO 2	--------				
BY 1	--------				
BY 2	--------	--------	--------	--------	
BE 1	--------	--------	--------	--------	
BE 2	--------				
Plot 1					-------*
Plot 2					-------*
Plot 3					-------*
Plot 4					-------*
Plot 5					-------*
Plot 6					-------*
Collections	66	8	26	40	62
Incident Samples	66	8	26	40	62
Throughfall Stations	25	8	16	8	6
Throughfall Samples	1650	64	416	320	372
Stemflow Stations	24	8	16	8	0
Stemflow Samples	814	39	275	178	0

------* = Stemflow not collected

6 THE DATA BASE

6.1 SIZE

Tables 5 and 6, which describe the collection strategies employed in this study, also report the number of collections and active stations used to monitor incident precipitation, throughfall and stemflow, at each catchment basin. Also reported are the number of samples resulting from these collections. This information is reported for each collection strategy.

Note that the number of incident and throughfall samples is a product of the number of stations and collections. This assumes that throughfall occurred at each station during every sampling period and that there were no accidental losses of sample. There were in fact rare cases when there were no throughfall samples as a result of a very light precipitation event. A 'sample' of depth equal to zero represents such cases in the data base. Where a sample was accidently lost, a record was created to generate such a sample. The procedure for dealing with accidental losses is discussed in the next section.

The number of stemflow samples represents the actual number of cases were stemflow of more than one litre occurred. The number of locations (boles) with stemflow could vary from zero to the maximum of stations active during the collection period, depending on the characteristics of the precipitation. The data base size statistics include cases where estimates of stemflow volume and chemistry were created to compensate for the accidental sample loss. The procedures used to recreate a lost sample are also discussed in the next section. Note that stemflow was not sampled during the fixed plot strategy. Also, Station MH 13 at Harp 4 did contain a stemflow collar, however the tree bole contained a major crack and the collar could not be attached properly. This resulted in consistently unreliable stemflow volume data. All stemflow data collected at this station were removed from the working database.

6.2 ORGANIZATION

Two key fields are required to identify any sample collected during the course of this study. These are the Sample Date and Location Code. During the periods employing the rain funnels, the Sample Date represents the calendar day during which the last part of the 'event' occurred. It **does not** represent the day the samples were removed from the field. During the period employing the snow collectors, the Sample Date **does** represent the day the samples were removed from the field. Recall that monitoring of precipitation characteristics by the tipping bucket gauge and recorder was not possible during the winter and it was not possible to record the time when precipitation stopped. All samples, incident, throughfall and stemflow, collected concurrently, have the same Sample Date.

The second key field is the Location Code. This field can best be explained by the following examples.

'PR-INC'	represents incident precipitation collected by the rain funnel at the Plastic Lake basin.
'HS-MS4b'	represents throughfall collected by the snow collector under the target canopy Soft Maple Number 4b at the Harp Lake Basin. The character 'b' identifies this as one of the replicated canopies.
'PS-PT3'	represents throughfall collected by snow collectors in Plot 3 at the Plastic Lake basin.
'HSF-BE2'	represents stemflow collected from target canopy American Beech number 2 at the Harp Lake basin.

To facilitate the recognition of each sampling period, all sample collections were assigned a sequential collection Reference Number extending over the entire study period. The same number was allocated to each sample collected at the respective basin at any time. The same number occurring for collections at both basins identifies a concurrent period of precipitation activity. Collections with the same Reference Number may have different Sample Dates. The most frequent cause of this apparent discrepancy is the cessation of precipitation on either side of midnight at the two basins.

A number applying to only one of the basins, signifies that precipitation activity did not occur at the other basin or that the samples do not represent concurrent activity or collection period. Some numbers do not apply to either basin. This signifies that precipitation was collected only at the Dorset Research Centre where an incident collector was co-located with collectors of other studies for intercomparison purposes. This referencing was used mainly in the validation procedures and data management.

The Reference Numbers begin at number 36. Monitoring of some nature began at Plastic 1 in early August, 1982, and in late August, 1982 at Harp 4. Since this was a new study, it was necessary to develop procedures and correct problems as the they became apparent. Consequently, data collected during the early phases of collection were of questionable quality. Once, collection with snow buckets began, a new set of problems had to be resolved. It was decided to exclude all collections with a Reference Number less than 36 from the data base, and therefore from any data analysis or interpretation.

6.3 PRELIMINARY EDITING

During the course of the study, data was continuously written to mainframe computer files. These data consisted of sample dates, numeric sampling location codes, sample numbers, sample volumes and a series of chemical concentrations for each sample. These files were continuously edited to ensure that the correct field and field laboratory information had been transcribed. This information included the sample date, location code, sample number, sample volume and pH. Field and field lab notes were compared to the contents of the mainframe files to ensure consistency. The balance of the chemical data, which was generated by the main laboratory, was also reviewed to identify apparent errors. If a transcription or laboratory error was confirmed, appropriate corrections were made to the mainframe files.

In addition, where no information was available for a sample due to accidental loss, an artificial record for this sample was created to ensure that it was not overlooked. Estimates for the missing data would be generated later.

Manual screening of mainframe data file reports identified chemical data that were **clearly** inconsistent with other data from similar, concurrent samples. These gross outliers could most easily be spotted in a listing of all throughfall samples collected at one time. Such suspect data could be a result of sample contamination or lab instrumentation and reporting errors. These were deleted from the mainframe files. Also deleted were chemical data reported as being greater than some value, since such information had limited value, and would create a bias if left in the data base as a real concentration. Estimates for these deleted data would also be created later.

7 DATA BASE EDITING AND VALIDATION

7.1 RATIONALE

As a result of such editing, the mainframe files contained records for each sample collected, or that should have been collected, and these records were correctly identified. However, many of these records were incomplete, with some or all observations missing, and otherwise not completely validated.

All available mainframe data were transferred to microcomputer applications for further editing, validation and creation of estimates for the voids.

The occurrence of erroneous or missing data could be ascribed to several causes. These are discussed below in decreasing order of frequency.

The most frequent cause of gaps in the data was due to insufficient sample volume for a complete chemical analysis. Since sampling was conducted on an event basis, it was not appropriate to wait for the subsequent precipitation activity to add sufficient volume to the samples.

Certain samples, especially those of small volume, could contain concentrations of analytes which exceeded the analytical range of the instrumentation. If there was insufficient sample for dilution and re-analysis the datum was reported as being greater than the instrumentation limit. These data had been deleted from the data base as mentioned above.

The third most common cause of missing information was the accidental losses of samples. This could occur before or during collection resulting in no information about the sample. A loss could occur during transport to the field lab, also resulting in no information unless a gravimetric determination of sample volume had been made at collection. Samples could also be lost at any stage of the chemical analysis resulting in only partial chemical information.

Recording and transcription errors, either by the field of laboratory personnel, contamination of or improper handling or preservation of samples, or laboratory instrument problems would result in erroneous information in the data base. Such errors were not always apparent during the preliminary screening and edit.

A significant source of error was related to the poor catch efficiency of the snow collectors which were situated on the towers. This highly exposed environment was subject to wind turbulence above the collector resulting in the capture of less than the actual incident depth of snow.

Finally, there was the possibility of contamination of a sample during collection by field crews, or in the transfer to various containers. Foreign substances could also be present in the sample. This would be especially evident in incident precipitation samples.

7.2 PROCEDURES

7.2.1 INCIDENT PRECIPITATION DEPTH

Since the data on depth of incident precipitation occurring at the study sites were critical to a valid interpretation of the throughfall process, it was vital that all erroneous or missing information for this parameter be replaced by the best estimate possible.

During the rain seasons, precipitation was collected by paired funnels on the tower. If the depths of the funnels, which were averaged, were not consistent or did not agree with the standard gauge, the record was edited to reflect the higher funnel depth. This procedure would have to improve the agreement between funnel and gauge depths. If both funnel depths were not consistent with the standard gauge the later was used. The remark 'dbl', representing a doubling of the higher funnel depth qualifies the depth datum. The remark 'std' represents cases were the standard gauge datum was used. Further evidence of an erroneous incident rain depth was the occurrence of several throughfall depths which were higher than the respective incident depth, an intuitively unacceptable condition.

Such changes also usually resulted in better agreement with precipitation depth observations made by an independent study operating in the basins, as well as eliminating the throughfall versus incident depth inconsistency.

This independent study, which shall be referred to as the WRB study, maintained incident collectors at the two basins as part of an investigation of hydrological and chemical budgets. The sampling periods used by the WRB study did not coincide with those of this study, and were invariably longer periods. Consequently, two or more of either study sampling periods were combined until a coincident sampling date was reached. This was not a difficult task since both studies collected samples after the cessation of precipitation and common sampling dates were frequent.

During the snow season, there was a recognized problem of poor catch efficiency by the un-shielded collectors on the towers. At the Plastic basin, a separate ground level snow collector was located on the un-forested rock outcrop and adjacent to the tower. The surrounding forest provided an effective wind break for the collection of snow. Most of the incident snow depths for this basin were based on this collector and have the remark 'grd' appended. This substitution invariably resulted in a good agreement with the independent WRB study depth records, while at the same time eliminated the incidence of higher than incident throughfall depths.

Such a ground level collector was not available at the Harp basin while poor catch efficiency was also a problem. The incident snow depths as recorded on the Harp tower were consistently lower than the concurrent throughfall depths and lower than the WRB study data.

To compensate for these erroneous incident snow depth data, histograms of the incident and throughfall depths were generated for each collection and intuitive estimates of valid depths made. While this procedure was being used, consideration was given to the type of snow fall that had occurred. This included the total amount, consistency, intensity and the probability that under some conditions the snow would be captured by the canopy only to be released during the subsequent collection period. Invariably when the winter precipitation was in the form of rain or wet snow, the catch efficiency would be good and the throughfall depths would be consistently less than the incident. In such cases, the actual collected depth was retained. While these estimates were being generated, the new depth values would be checked for agreement with the WRB study data. The remark 'tda' was appended to the estimated incident snow depths to represent a throughfall depth adjusted value.

This method was also used for three of the Plastic basin incident snow depth estimates were the ground level collector was disturbed or its data was considered unreliable.

On three occasions, the WRB study depth was used to replace Harp basin incident snow depth when other procedures could not be applied. In these cases the sampling periods of the two studies were concurrent. These depth data have been identified with the remark 'wrb'.

7.2.2 THROUGHFALL DEPTH

No *post facto* changes were made to the throughfall rain or snow depth data. The position of these collectors in a forest stand provided an ideal wind break so that the collected depths would be an accurate representation of below canopy precipitation penetration.

However, over the course of the study there were cases where a given throughfall station collector was disturbed or depth data was incomplete. During the rain periods, this consisted of a loss of information from one or more of the throughfall funnels positioned under a target canopy or from one or more of the funnels on the plot grids. The depth data was then solely derived from the remaining collector(s). This reliance on a single collector was also made during the snow period when the plot strategy was used since there were three snow collectors used at each plot. The remark 'E' identifies all throughfall depth data that was obtained in a less than optimum manner.

In a few cases, there was no throughfall depth data for a given station at all. This occurred primarily where only a single snow throughfall collector was used beneath a target canopy and it was disturbed or the depth was not recorded. In these situations, a surrogate collection period or rain event was identified. This surrogate would have similar incident depth and would be as close as possible in time to the event with the missing datum. A ratio consisting of the summed throughfall depths available for both events was calculated and this ratio was applied to the missing datum station in the surrogate event to generate a value for the missing data point. The remark 'E' was also used to identify all throughfall depths so derived.

Using the above described procedures resulted in a complete and more accurate record of incident and throughfall depths for all stations throughout the duration of the study. This eliminated the need for a general extrapolation to account for any missing depth data which would not have considered individual precipitation characteristics or other variables.

7.2.3 STEMFLOW VOLUME

Correcting erroneous or estimating missing stemflow volumes presented a unique problem. Unlike incident or throughfall depth which could be compared to independent but related observations, stemflow volumes could only be obtained from actual observations. If a sample was partially or completely spilled, if the collar was blocked by ice or debris, or if a collector overflowed, the volume had to be estimated.

A flagged preliminary estimate was added to the mainframe files as a place-holder for the sample record. After the data were transferred to a microcomputer environment, all such estimates were deleted. Since all sampling was complete, the data base contained the maximum number of valid observations.

All sampling periods that contained complete and valid stemflow volumes were isolated and the total volume of stemflow for each bole was calculated. To produce an estimate for a missing volume within a sampling period, a series of ratios between the individual, valid volumes of that sampling period and the respective total volumes were calculated. The average of these ratios was applied to total stemflow volume for that bole to generate the estimate for the missing stemflow volume.

In this way, the estimate was based on both the long term stemflow record from the given tree bole as well as on the flows from the other boles for the given sampling period. For this approach to be operational required grouping of sampling periods having the same sampling strategy or phase. The procedure would operate as long as there was at least one valid volume observation for each sampling period. The remark 'sfe' was appended to all stemflow volumes derived in this way.

7.2.4 INCIDENT PRECIPITATION CHEMISTRY

Considerable effort was expended in the validation or interpolation of incident precipitation chemical data. Two broad approaches were used in these procedures. The first involved checks of the internal consistency of the chemistry of a sample. The second involved comparisons of data for samples collected by other collectors and by other studies, at nearby locations.

One internal integrity test checked the ion balance of a sample. Since the analyses performed on these samples included all major ions, and it was unlikely that incident precipitation samples contained appreciable quantities of dissociated organic compounds, it was possible to determine the discrepancy between anion and cation concentrations. Consequently, if this test indicated that the anions and cations were in balance, then it was unlikely that any one concentration was in error. The following calculations were performed to determine the discrepancy between the reported anion and cation concentrations. All concentrations are reported in milligrams per litre.

$$\% \text{ Discrepancy} = \frac{\text{Anion equivalence} - \text{Cations equivalence}}{\text{Anion equivalence} + \text{Cations equivalence}} \times 200$$

where:

Anion equivalence =

$$\frac{[SO_4]}{48.0288} + \frac{[NO_3\text{-}N]}{14.0067} + \frac{[Cl]}{35.453} + \frac{4.90}{1000 \times 10^{-pH+6}}$$

Cation equivalence =

$$10^{(-pH+3)} + \frac{[NH_4\text{-}N]}{14.0067} + \frac{[Ca]}{20.04} + \frac{[K]}{39.0983} + \frac{[Mg]}{12.1525} + \frac{[Na]}{22.9898}$$

The second internal integrity test checked the measured pH against a pH value that was predicted from the concentrations of other ions in the sample. This test was especially valuable since pH was potentially the least stable chemical measurement made. The calculations accommodated dissolved atmospheric CO_2 in the sample.

The discrepancy between measured pH and the pH predicted by the ionic composition of the incident precipitation sample was determined as follows:

$$\% \text{ Discrepancy} = \frac{pH_{measured} - pH_{predicted}}{pH_{measured} + pH_{predicted}} \times 200$$

The predicted pH was derived from the calculated hydrogen ion concentration. With all ion concentrations expressed in milligrams per litre, the latter was determined as follows:

$$[H+] = \frac{(\text{Net Ions}) + ((\text{Net Ions})^2 + 4(K_H \times K_1 \times PCO_2))^{1/2}}{2}$$

where:

$$\text{Net Ions} = \frac{[SO_4]}{48.0288} + \frac{[NO_3\text{-}N]}{14.0067} + \frac{[Cl]}{35.453} - \frac{[NH_4\text{-}N]}{14.0067} - \frac{[Ca]}{20.04} - \frac{[K]}{39.0983} - \frac{[Mg]}{12.1525} - \frac{[Na]}{22.9898} \times 1000$$

and: $K_H = 0.034 \times 10^6$ ueq/L/atm *Henry's Law Constant*
$K_1 = 0.45$ ueq/L *First CO_2 Dissociation Constant*
$PCO_2 = 320 \times 10^6$ atm *CO_2 Partial Pressure*

These two internal integrity tests would not identify sample contamination by an ionic compound consisting of a major anion and cation. To check for such occurrences and to produce estimates for missing data, data for concurrent precipitation events in the same geographic area was consulted.

As mentioned previously, each collection period for the two study basins was assigned a reference number. An identical number indicated a concurrent sampling period. In addition to these two locations, identical collectors were operated at the Dorset Research Centre (DRC) by this study. These sampling periods were similarly referenced, a relatively easy task since all three stations were usually sampled on the same day.

A fourth set of data was available from an automated wet only collector, also located at the DRC and operated by the APIOS Deposition Network. These samples were collected daily and as a result there were usually more than one sample coinciding with this study's sampling period. To make use of this fourth data set required the identification of the daily samples which coincided with the sampling periods for this study and calculating the depth weighted concentrations for these series of daily samples. The resultant groups of daily samples were assigned the same series of reference numbers.

By using the common referencing scheme, it was possible to compare the chemistry of any one incident sample to three others concurrently sampled. This was accomplished by merging all four data sets and comparing individual data from each set. A concentration reported for an incident precipitation sample collected at one of the basins was compared to concomitant data from the other sources. If precipitation characteristics, primarily depth, were similar, the suspect datum was flagged.

An additional source of information for validating incident precipitation chemistry resided in the chemistry data for throughfall samples collected along with the incident sample at the basin. Certain assumptions could be drawn from the major trends between the incident and throughfall chemistry. These were that sulphate, chloride, calcium, magnesium, potassium and sodium were enriched in throughfall. The other ions, namely hydrogen, nitrate and ammonium could be enriched or reduced. Consequently, if the reported throughfall concentrations for the ions that were expected to be enriched were consistently lower than in the incident sample, the incident sample concentration was considered suspect.

The editing and validation of the incident precipitation chemistry was performed by using all the tests and sources of validating information simultaneously. Electronic spreadsheets containing the incident data from each basin and the formulae for internal integrity checks were prepared. A common spreadsheet containing merged data from all four sources was likewise on hand, as was a listing of incident data which conflicted with throughfall data.

The data files contain the remark "C" identifying incident precipitation chemistry data which were changed from that reported from the chemical analysis. The remark "E" is used to identify estimated data where there was no analytical result reported.

Data installed into the database and flagged with "C" or "E" had to be compatible with all validation processes. Thus, the data could not conflict with the throughfall, had to agree with the other incident precipitation data sources and had to result in agreement in the internal integrity checks.

The results of these validation and editing procedures was to have a chemical concentration value for each major ion and each sample in the incident precipitation database for each basin.

7.2.5 THROUGHFALL CHEMISTRY

All throughfall chemical data was manually screened to identify cases where values were outliers from the range created by the other throughfall locations. This was the second such screening, in addition to the preliminary screening conducted while the data was resident on the mainframe computer. The remaining outliers were deleted.

The remaining throughfall data was now considered valid although there where a large number of voids created by the deletions and where no data were generated. Internal integrity checks were not performed because it was known that the chemical analyses performed were not inclusive enough to cover all possible ions in such samples. Organic anions, for example, would have a significant contribution to the ion balance and predicted pH calculations. These were not analyzed.

The chemical data voids were filled by using a ratio estimation technique. This technique is described below.

All collection periods were separated on the basis of throughfall sampling strategy or phase. This provided data sets consisting of the same series of collector locations. Further segregation was made on the basis of whether the rain or snow collectors were used. This isolated possible seasonal influences.

Data sets within each new grouping which did not contain any voids for a given analyte were identified and simple, unweighted, grand mean concentrations for each collector location were calculated.

When a data set with a missing value was encountered, a series of ratios between available concentrations and the respective grand mean concentrations were generated. The average of these ratios was then calculated.

This average ratio was then applied to the grand mean concentration corresponding to the collector location with the data void to produce an estimated concentration.

This technique had the advantage of taking into consideration the chemistry of throughfall collected at a given location over the course of a collection strategy or phase as well as considering the chemistry of throughfall collected at other locations during the same collection period. Throughfall chemistry concentrations generated by this technique were added to the data base and flagged with the remark 'RT'.

To use this technique required at least one valid chemical concentration for one sampler location within each data set. There were cases where all concentration data for a certain chemical were missing. This occurred when very small volumes of sample were collected and there was insufficient sample for analysis of all chemicals. This required a different approach to produce estimates.

The approach adopted consisted of conducting linear regression analyses between all ion pairs from each sampling location within the sampling strategy or phase. The ion which had the best correlation with the missing ion was used in the regression equation to calculate the missing value. Values so estimated were installed in the data base with the remark 'RG'.

These two procedures completely filled the chemical data base for major ions in throughfall.

7.2.6 STEMFLOW CHEMISTRY

Stemflow chemistry was notable in the wide range of concentrations which could occur. A preliminary examination of the data suggested that the quality of stemflow was dependant on total flow as well as the tree species. The validation and estimation procedures would be based on these considerations. Procedures such as the ratio or regression techniques applied to estimate missing throughfall chemistry would be inappropriate because, unlike throughfall depths which fell within a narrow range for each precipitation period, stemflow volumes could vary by orders of magnitude.

The procedure used to fill missing stemflow chemistry data was to isolate each unique bole for the entire study period, without regard to the sampling strategy. A correlation matrix was generated for each bole containing the correlation coefficients between major ions plus volume. Whenever a stemflow record with a missing ion concentration was encountered, the matrix was examined to determine which other ion or volume had the best correlation with the missing ion. If the stemflow record contained a valid concentration for this other ion, the missing ion concentration would be calculated using this other ion as the required variable.

Frequently, the other ion was not the first choice based on the matrix because the stemflow record had several missing ion concentration data. At times there were no ion data, only a volume. In such cases all missing ion concentrations were calculated using volume as the variable.

If the correlation between the ions was significant ($p = 0.05$), the calculated ion concentration was added to the data base. This procedure was repeated to fill more missing data, but on a more complete data base. The remark codes 'RG1' to 'RG6' represent the first through sixth passes using this procedure, at which each datum was added. Subsequent passes failed to add to the data base. This left a relatively small number of chemical data that had to be estimated in another manner.

These data were generated by identifying a stemflow sample from the same tree, with a similar volume and occurring during the same season. The appropriate datum was copied from this sample record to the incomplete sample record. The remark code 'SUR' identifies such copied data.

8 CALCULATION OF MEAN CONCENTRATIONS

The data files appended to this report contain ion concentration data for the various samples collected during the course of this study. To reduce these data to manageable proportions will require some mathematical manipulations. Following are suggested approaches for data reduction based on the sampling design principles of this study.

8.1 INCIDENT PRECIPITATION

Single measurements represent depths of rain 'events' or weekly snowfall, and concentrations of major ions. Calculating mean ion concentrations requires weighting the individual concentrations by the respective depths for the period of interest.

8.2 THROUGHFALL

The throughfall sampling strategies employed in this study were designed to simplify the assessment of the influence of the watershed forests on precipitation quantity and quality. The stratified placement of throughfall collectors considered basal area dominance of tree species. Likewise, the placement of collectors in fixed plots considered the stand types on the watersheds.

Calculation of mean ion concentrations in throughfall for each sampling period can be accomplished by depth weighting the individual ion concentrations for all collector locations. This can be applied to the intensive and reduced stratified sampling strategies. It should be recalled that during the reduced stratified strategy, there was a period where certain sampling locations were 'replicated'. The data from these locations should be given separate consideration and not included in depth weighting calculations unless averages for these replicates are first determined.

The throughfall sampled by the plot strategy requires special consideration if the total watershed forest is under consideration. At Plastic Lake No. 1, six plots were established, two each in Stands 'A','D' and 'E'. At Harp Lake No. 4, two plots were established in Stand 'C' and one each in Stands 'A', 'B', 'D' and 'F'. Since the stands represent varying proportions of the watersheds, throughfall as collected at the different plots should be weighted when determining the throughfall characteristics of the portions of watershed forest under investigation.

Table 7 presents the weighting factors to be applied to the plot throughfall data to improve the representation of the whole watershed forest. Note, however, that neither the whole of the watersheds nor their forested portions are completely represented under any sampling scheme.

TABLE 7: Weighting Factors for Plot Throughfall Collections

Harp Lake No. 4				Plastic Lake No. 1			
Plot No.	Stand	Stand Area (ha)	Weighting Factor	Plot No.	Stand	Stand Area (ha)	Weighting Factor
PT 1	B	15.82	0.2224	PT 1	D	(1.90)	0.0579
PT 2	F	7.81	0.1098	PT 2	D	1.90	0.0579
PT 3	C	14.33	0.1007	PT 3	E	(1.80)	0.0548
PT 4	C	(14.33)	0.1007	PT 4	E	1.80	0.0548
PT 5	D	11.40	0.1602	PT 5	A	12.72	0.3873
PT 6	A	21.78	0.3062	PT 6	A	(12.72)	0.3873
	Total	71.14	1.0000		Total	16.42	1.0000

8.3 STEMFLOW

The magnitude of flow of precipitation water down the boles of trees is highly dependant on the bark characteristics (hence species) and size of the tree (DBH). Also, different species appear to have greatly differing effects on the chemistry of the water that flow down the bole.

Consequently, the calculation of mean stemflow concentrations as well as determining the significance of stemflow as a hydrologic pathway requires detailed information on the forest characteristics. This includes species composition, size class distribution as well as density of trees in various species/size classes.

Tables 8 and 9 summarize the distributions of tree stems in the two watershed basins. The DBHs of the sample trees are given, along with the range of DBHs of trees of that species in the basin meant to be represented by the sample tree. The density of a given size range of trees in stems per hectare is required information to calculate fluxes of chemicals via stemflow. The weighting factor is a ratio of the density of trees in the size class to the density of all trees species and size classes listed.

TABLE 8: Tree Stem Distribution - Plastic Lake No. 1

INTENSIVE STRATIFIED STRATEGY				
Tree Bole	DBH (cm)	Stand Range* DBH (cm)	Stems/Ha	Weighting Factor
PW1	15.5	10 - 16	26.85	0.04721
PW2	16.9	18	8.28	0.01456
PW3	19.7	20	11.84	0.02082
PW4	22.3	22	14.24	0.02504
PW5	24.6	24 - 26	31.17	0.05480
PW6	29.1	28	11.65	0.02048
PW7	29.5	30	11.57	0.02034
PW8	31.8	32 - 34	19.56	0.03439
PW9	36.8	36 - 38	13.93	0.02449
PW10	39.5	40	5.93	0.01043
PW11	43.9	42 - 48	16.53	0.02906
PW12	52.7	50 +	3.09	0.00543
HE1	13.6	10 - 14	71.75	0.12614
HE2	15.4	16	23.34	0.04103
HE3	17.4	18	16.71	0.02938
HE4	21.3	20 - 22	38.44	0.06758
HE5	23.7	24 - 26	17.07	0.03001
HE6	29.3	28 +	18.61	0.03272
MS1	13.8	10 - 14	63.83	0.11222
MS2	18.1	16 - 18	56.21	0.09882
MS3	21.4	20 - 22	26.53	0.04664
MS4	23.2	24 +	18.48	0.03249
OR1	22.4	10 - 26	20.69	0.03638
OR2	30.5	28 - 34	10.67	0.01876
OR3	40.1	36 +	11.82	0.02078

REDUCED STRATIFIED STRATEGY				
Tree Bole	DBH (cm)	Stand Range* DBH (cm)	Stems/Ha	Weighting Factor
PW3	19.7	10 - 22	61.21	0.10761
PW7	29.5	24 - 34	73.95	0.13001
PW11	43.9	36 +	39.48	0.06941
HE3	17.4	10 - 22	150.24	0.26414
HE6	29.3	24 +	35.68	0.06273
MS2	18.1	10 - 18	120.04	0.21104
MS4	23.2	20 +	45.01	0.07913
OR2	30.5	10 +	43.18	0.07592

* DBH range of trees on the watershed represented by designated tree bole

TABLE 9: Tree Stem Distribution - Harp Lake No. 4

INTENSIVE STRATIFIED STRATEGY

Tree Bole	DBH (cm)	Stand Range* DBH (cm)	Stems/Ha	Weighting Factor
MH1	13.3	12 - 14	71.85	0.17955
MH2	15.3	16	27.91	0.06975
MH3	18.5	18	26.23	0.06555
MH4	19.8	20	23.02	0.05753
MH5	22.0	22	16.57	0.04141
MH6	24.3	24	15.33	0.03831
MH7	26.3	26	10.41	0.02601
MH8	28.0	28	8.41	0.02102
MH9	30.5	30	6.50	0.01624
MH10	31.5	32	5.33	0.01332
MH11	35.8	34 - 38	8.41	0.02102
MH12	41.5	40 +	4.64	0.01160
MS1	13.0	12 - 16	32.23	0.08054
MS2	20.0	18 - 20	18.02	0.04503
MS3	22.3	22	7.97	0.01992
MS4	25.0	24 - 26	10.37	0.02591
MS5	28.0	28 - 32	7.97	0.01992
MS6	39.3	34 +	5.12	0.01279
PO1	24.3	12 - 30	26.62	0.06652
PO2	36.8	32 +	4.90	0.01224
BY1	19.8	12 - 26	21.98	0.05493
BY2	32.3	28 +	8.19	0.02047
BE1	20.0	12 - 26	24.26	0.06062
BE2	34.0	28 +	7.93	0.01982

REDUCED STRATIFIED STRATEGY

Tree Bole	DBH (cm)	Stand Range* DBH (cm)	Stems/Ha	Weighting Factor
MH1	13.3	12 - 16	99.76	0.24929
MH5	22.0	18 - 28	99.97	0.24982
MH11	35.8	30 +	24.88	0.06217
MS2	20.0	12 - 22	58.22	0.14549
MS4	25.0	24 +	23.46	0.05863
PO1	24.3	12 +	31.52	0.07877
BY2	32.3	12 +	30.17	0.07539
BE1	20.0	12 +	32.19	0.08044

* DBH range of trees on the watershed represented by designated tree bole

9 APPENDICES

The appendices to this report consist of eight spreadsheet files prepared in an MS DOS microcomputer environment using Lotus 1-2-3, ver. 2.x software. The contents of each file are described below. They are configured to print in a landscape orientation on a Hewlett-Packard Laserjet series printer. The files are contained on three 3.5 ", 1.44 Mb floppy disks. Sample pages from these files are attached to this report. Copies of these disks and this report are available from:

Ministry of Environment and Energy
Dorset Research Centre
Bellwood Acres Road
Dorset, Ontario
P0A 1E0
Attn: B. LaZerte

9.1 PLASTIC LAKE NO. 1 INCIDENT AND THROUGHFALL

Three files contain incident precipitation and throughfall data collected at Plastic Lake No. 1 during the course of this study. The data have been compiled in the separate files along sampling strategies. File names and periods of coverage are as follows:

PL_TF_1.WK1	Intensive Stratified - Reference Nos. 36 - 103
PL_TF_2.WK1	Reduced Stratified - Reference Nos. 104 - 185
PL_TF_3.WK1	Plots - Reference Nos. 187 - 255

9.2 HARP LAKE NO. 4 INCIDENT AND THROUGHFALL

Incident precipitation and throughfall data for Harp Lake No. 4 have been compiled in comparable files. These are:

HL_TF_1.WK1	Intensive Stratified - Reference Nos. 36 - 103
HL_TF_2.WK1	Reduced Stratified - Reference Nos. 104 - 186
HL_TF_3.WK1	Plots - Reference Nos. 188 - 256

9.3 PLASTIC LAKE NO. 1 AND HARP LAKE NO. 4 STEMFLOW

Stemflow was only collected during the intensive and reduced stratified sampling strategies. During some precipitation periods, there was no stemflow from any of the monitored trees. The data files exclude any reference to such cases. However, if stemflow occurred from at least one of the trees, all trees being monitored are listed, frequently with volume equal to zero.

Two files are used to contain stemflow data. PL_SF.WK1 contains Plastic Lake No. 1 data. HL_SF.WK1 contains Harp Lake No. 4 data.

PLASTIC LAKE - Incident Precipitation and Throughfall Chemistry

LOCATION	SAMPLE DATE	REF NO	DEPTH mm	pH	H mg/L	SO4 mg/L	NO3-N mg/L	Cl mg/L	Ca mg/L	Mg mg/L	K mg/L	Na mg/L	NH4-N mg/L
PS-INC	05-Jan-83	36	6.56 grd	4.35	0.0447	2.50	0.95	0.40	0.91	0.155	0.030	0.180	0.428
PS-PW1	05-Jan-83	36	4.79	4.67	0.0214	2.45	1.08	0.50	1.47	0.260	0.075	0.235	0.324
PS-PW2	05-Jan-83	36	3.96	4.60	0.0251	2.90	1.19	0.51	1.57	0.290	0.055	0.220	0.390
PS-PW3	05-Jan-83	36	3.02	4.58	0.0263	3.15	1.29	0.54	1.71	0.315	0.065	0.240	0.422
PS-PW4	05-Jan-83	36	3.72	4.60	0.0251	2.95	1.24	0.53	1.62	0.295	0.050	0.230	0.376
PS-PW5	05-Jan-83	36	3.21	4.64	0.0229	3.20	1.29	0.58	1.78	0.380	0.070	0.290	0.418
PS-PW6	05-Jan-83	36	3.53	4.59	0.0257	3.10	1.27	0.54	1.65	0.300	0.045	0.240	0.418
PS-PW7	05-Jan-83	36	3.88	4.58	0.0263	2.80	1.16	0.49	1.53	0.275	0.050	0.215	0.386
PS-PW8	05-Jan-83	36	4.19	4.56	0.0275	2.65	1.12	0.47	1.40	0.275	0.050	0.210	0.380
PS-PW9	05-Jan-83	36	3.13	4.50	0.0316	3.15	1.30	0.53	1.68	0.300	0.060	0.230	0.444
PS-PW10	05-Jan-83	36	3.56	4.58	0.0263	3.00	1.22	0.51	1.61	0.295	0.060	0.235	0.412
PS-PW11	05-Jan-83	36	2.83	4.57	0.0269	3.35	1.40	0.58	1.91	0.345	0.055	0.270	0.474
PS-PW12	05-Jan-83	36	3.61	4.57	0.0269	2.85	1.18	0.52	1.49	0.275	0.055	0.235	0.366
PS-HE1	05-Jan-83	36	2.61	4.69	0.0204	3.50	1.48	0.64	2.01	0.380	0.050	0.310	0.464
PS-HE2	05-Jan-83	36	3.24	4.53	0.0295	3.60	1.44	0.60	1.86	0.345	0.105	0.270	0.510
PS-HE3	05-Jan-83	36	2.06	4.72	0.0191	3.55	1.47	0.64	2.03	0.380	0.105	0.290	0.604
PS-HE4	05-Jan-83	36	3.10	4.57	0.0269	3.25	1.38	0.58	1.85	0.325	0.060	0.250	0.448
PS-HE5	05-Jan-83	36	2.84	4.66	0.0219	3.50	1.43	0.80	1.92	0.355	0.120	0.400	0.466
PS-HE6	05-Jan-83	36	2.44	4.71	0.0195	3.50	1.47	0.63	2.05	0.375	0.075	0.300	0.456
PS-MS1	05-Jan-83	36	4.24	4.63	0.0234	2.75	1.20	0.51	1.46	0.265	0.060	0.250	0.374
PS-MS2	05-Jan-83	36	4.13	4.64	0.0229	2.90	1.26	0.51	1.59	0.275	0.040	0.235	0.384
PS-MS3	05-Jan-83	36	4.43	4.71	0.0195	2.75	1.16	0.49	1.52	0.270	0.050	0.220	0.354
PS-MS4	05-Jan-83	36	5.99	4.58	0.0263	2.40	1.02	0.38	1.15	0.195	0.060	0.150	0.348
PS-OR1	05-Jan-83	36	3.91	4.66	0.0219	2.75	1.17	0.48	1.48	0.265	0.065	0.215	0.344
PS-OR2	05-Jan-83	36	4.66	4.57	0.0269	2.65	1.11	0.44	1.31	0.225	0.045	0.175	0.364
PS-OR3	05-Jan-83	36	4.56	4.56	0.0275	2.60	1.08	0.41	1.24	0.215	0.040	0.170	0.374

HARP LAKE - Incident Precipitation and Throughfall Chemistry

LOCATION	SAMPLE DATE	REF NO	DEPTH	pH	H mg/L	SO4 mg/L	NO3-N mg/L	Cl mg/L	Ca mg/L	Mg mg/L	K mg/L	Na mg/L	NH4-N mg/L
HR-INC	12-May-84	118	9.58	4.05	0.0891	6.60	1.12	0.38	0.98	0.155	0.290	0.175	1.250
HR-MH1	12-May-84	118	8.67	4.37	0.0427	8.10	1.21	0.33	1.43	0.385	2.950	0.085	1.800
HR-MH5	12-May-84	118	7.19	4.70	0.0200	8.05	1.17	0.37	1.31	0.415	3.520	0.110	2.450
HR-MH11	12-May-84	118	8.18	4.26	0.0550	8.30	1.17	0.35	1.48	0.350	2.950	0.105	1.850
HR-MS2	12-May-84	118	7.69 E	4.15	0.0708 RT	7.59 RT	1.07 RT	0.51 RT	1.54 RT	0.348 RT	1.784 RT	0.114 RT	1.274 RT
HR-MS4	12-May-84	118	5.55	3.93	0.1175	9.05	1.78	0.45	2.50	0.410	1.420	0.150	1.550
HR-PO1	12-May-84	118	7.89	4.16	0.0692	8.20	1.15	0.28	1.69	0.410	2.650	0.085	1.300
HR-BY2	12-May-84	118	8.75	4.53	0.0295	8.75	1.18	0.39	2.06	0.700	3.620	0.130	1.350
HR-BE1	12-May-84	118	7.69	4.13	0.0741	7.60	1.24	0.31	1.34	0.300	1.500	0.100	1.750
HR-MH1b	12-May-84	118	7.95	4.08	0.0832	7.15	1.19	0.33	1.22	0.215	0.880	0.160	1.300
HR-MH1c	12-May-84	118	8.40	4.09	0.0813	7.40	1.11	0.29	1.23	0.260	1.000	0.085	1.250
HR-MH5b	12-May-84	118	7.72	4.20	0.0631	7.35	1.12	0.29	1.25	0.265	1.520	0.095	1.650
HR-MH5c	12-May-84	118	9.10	4.05	0.0891	8.25	1.09	0.30	1.58	0.385 RT	0.945	0.080	1.100
HR-MH11b	12-May-84	118	8.92	4.69	0.0204	9.05	1.16	0.36	1.76	0.485	4.580	0.095	2.300
HR-MH11c	12-May-84	118	8.17	5.16	0.0069	10.40	0.31	0.87	2.35	0.550	6.500	0.100	3.000
HR-MS2b	12-May-84	118	8.52	4.10	0.0794	7.55	1.01	0.29	1.72	0.235	0.720	0.095	1.250
HR-MS4b	12-May-84	118	8.42	4.10	0.0794	7.50	1.03	0.33	1.23	0.260	2.720	0.115	1.150

PLASTIC LAKE - Stemflow Chemistry

LOCATION	SAMPLE DATE	REF NO	VOLUME L	pH	H mg/L	SO4 mg/L	NO3-N mg/L	Cl mg/L	Ca mg/L	Mg mg/L	K mg/L	Na mg/L	NH4-N mg/L
PSF-PW1	31-May-83	59	0.50	3.36	0.4365	41.40	0.06 RG1	0.60	6.90	0.980	5.500	0.400	0.106
PSF-PW2	31-May-83	59	0										
PSF-PW3	31-May-83	59	0										
PSF-PW4	31-May-83	59	0										
PSF-PW5	31-May-83	59	0										
PSF-PW6	31-May-83	59	0.55	3.56	0.2754	26.20	0.01 RG1	0.56	5.20	0.720	3.640	0.300	0.086
PSF-PW7	31-May-83	59	2.75	3.72	0.1905	22.20	0.18 RG1	0.44	4.90	0.580	4.120	0.150 <T	0.090
PSF-PW8	31-May-83	59	0.15	3.40	0.3981	37.40	0.04 RG1	0.78	6.70	1.040	4.500	0.300	0.062
PSF-PW9	31-May-83	59	4.25	3.65	0.2239	25.80	0.08 RG1	0.52	5.00	0.720	4.640	0.300	0.070
PSF-PW10	31-May-83	59	0										
PSF-PW11	31-May-83	59	6.25	3.72	0.1905	21.50	0.02 RG1	0.42	3.30	0.540	5.100	0.200 <T	0.074
PSF-PW12	31-May-83	59	11.25	3.71	0.1950	22.50	0.02 SUR	0.50	4.20	0.600	4.740	0.250	0.080
PSF-HE1	31-May-83	59	0										
PSF-HE2	31-May-83	59	0										
PSF-HE3	31-May-83	59	3.75	3.75	0.1778	17.80	0.55 RG1	0.50	3.20	0.460	1.380	0.050 <T	0.088
PSF-HE4	31-May-83	59	4.00	3.73	0.1862	17.00	0.08 SUR	0.40	3.20	0.280	1.100	0.050 <T	0.090
PSF-HE5	31-May-83	59	2.00	3.76	0.1738	16.60	0.15 RG1	0.36	3.00	0.300	1.640	0.050 <T	0.086
PSF-HE6	31-May-83	59	5.50	3.76	0.1738	17.80	0.02	0.38	3.50	0.380	1.300	0.050 <T	0.068
PSF-MS1	31-May-83	59	0.50	4.56	0.0275	21.60	0.20	0.24	2.80	0.340	17.200	0.050 <T	0.076
PSF-MS2	31-May-83	59	0										
PSF-MS3	31-May-83	59	3.00	4.43	0.0372	16.50	0.02	0.20	2.40	0.220	11.800	0.050 <T	0.002 <W
PSF-MS4	31-May-83	59	4.75	4.91	0.0123	16.00	0.02	0.18	3.60	0.260	13.100	0.050 <T	0.002 <W
PSF-OR1	31-May-83	59	4.75	4.53	0.0295	10.70	0.02	0.10	3.00	0.160	4.200	0.050 <W	0.026
PSF-OR2	31-May-83	59	6.25	4.35	0.0447	14.60	0.02	0.10	3.60	0.280	7.160	0.050 <W	0.050
PSF-OR3	31-May-83	59	27.00	4.61	0.0245	10.30	0.02	0.08	3.10	0.280	3.720	0.050 <T	0.044